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ABSTRACT

This training package consists of materials for use in training industrial arts students in the proper use and care of basic precision measuring instruments used in the machine trades. Outlined first are the basic objectives of the training program. The second part of the package includes task analyses for each of the measuring instruments. Two tests for use in assessing students' pre-training and post-training knowledge and skills are also included. The remainder of the package consists of a series of instructional handouts and transparencies that have been developed to assist instructors' presentations and demonstrations. (MN)

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TRAINING PACKAGE IN MEASUREMENT FOR MACHINISTS

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The enclosed materials were originally developed as an instructional aid for use by instructors who intend to train students in the proper use and care of basic precision measuring instruments used in the machine trades. The materials may be used by teachers of industrial arts or vocational programs within secondary schools. They may also be used by technical trainers who are teaching the principles of measurement within an industrial organization.

It is critical for students in a machine trades program to learn to properly use the basic measuring instruments which are commonly used in industry. In industrial practice, errors must be kept to a minimum. This training package follows a basic instructional model for training by incorporating training objectives, task analyses, a pre-training assessment instrument, and a post-training assessment instrument into the program.

The measuring instruments which have been used for this training program are the English and metric steel rule, hand-held inch and metric micrometer, English and metric vernier calipers, and vernier height gauge. These instruments are among the most commonly used tools used by machinists for precision measurement.

The first part of the training package includes the basic objectives of the training program. The objectives are written in behavioral terms, listing the behavioral task to be performed, the condition under which it is to be done, and including a criteria

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of acceptable performance.

The second part of the package includes the task analyses for each of the measuring instruments. The analyses were constructed in the form of flow charts. They include steps that are in sequential order, with each step defined and delineated so that no further description is necessary.

Tests used to assess the pre-training and post-training knowledge and skills which a trainee possess were also devised. The pre-training assessment determines the knowledge and skills that a trainee or student possesses before any formal training is conducted. The post-training assessment determines the knowledge and skills that a trainee or student possesses after the training is completed. The difference in the results of the assessments can help determine the effectiveness of the training and instruction and measure an individual's growth.

The two tests are prepared as Form A and Form B. It is not important which form is used as the pre-test or post-test as the tests have exactly the same number of items and are nearly identical. Answer sheets and overall score forms to record an individual's test score are also included.

There have been many instructional handouts, transparencies, and other aids that have been assembled to assist an instructor's presentations and demonstrations. Some of the prepared materials are included with this training package. Several books with units of instruction relating to measuring tools were used to supplement the instructional process, and provide illustrations of the proper use and care of particular types of precision measuring instruments.

The Training Package in Measurement for Machinists was developed and pilot-tested with several students enrolled in the Electrical Engineering Technology Program at Purdue University, West Lafayette, Indiana. The pre-training assessment was administered, instruction was given on the proper use and care of precision measuring instruments used in the machine trades, and the post-training assessment was administered. The entire training was conducted over a 3 day period. Based upon a comparison of pre-test and post-test results of the individuals involved in the pilot study, it appeared that the training was relatively effective. The students were near the 100% mastery level on the questions included in the post-training assessment.

The objectives, task analyses, test items, and instructional materials may be modified to change or expand the perspective of the training package. Selected instructional materials and aids may also be devised and adopted for use in the instructional process. It is possible for students or trainees to be taught the proper use and care of other precision measuring instruments that are used in the machine trades as well. The training package appears to be effective for the use in which it was originally intended. However, it is relatively flexible so that instructors can make modifications to the content of the package based on individual needs.

measurement
for
machinists



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TRAINING PACKAGE IN MEASUREMENT
FOR
MACHINISTS

OBJECTIVES

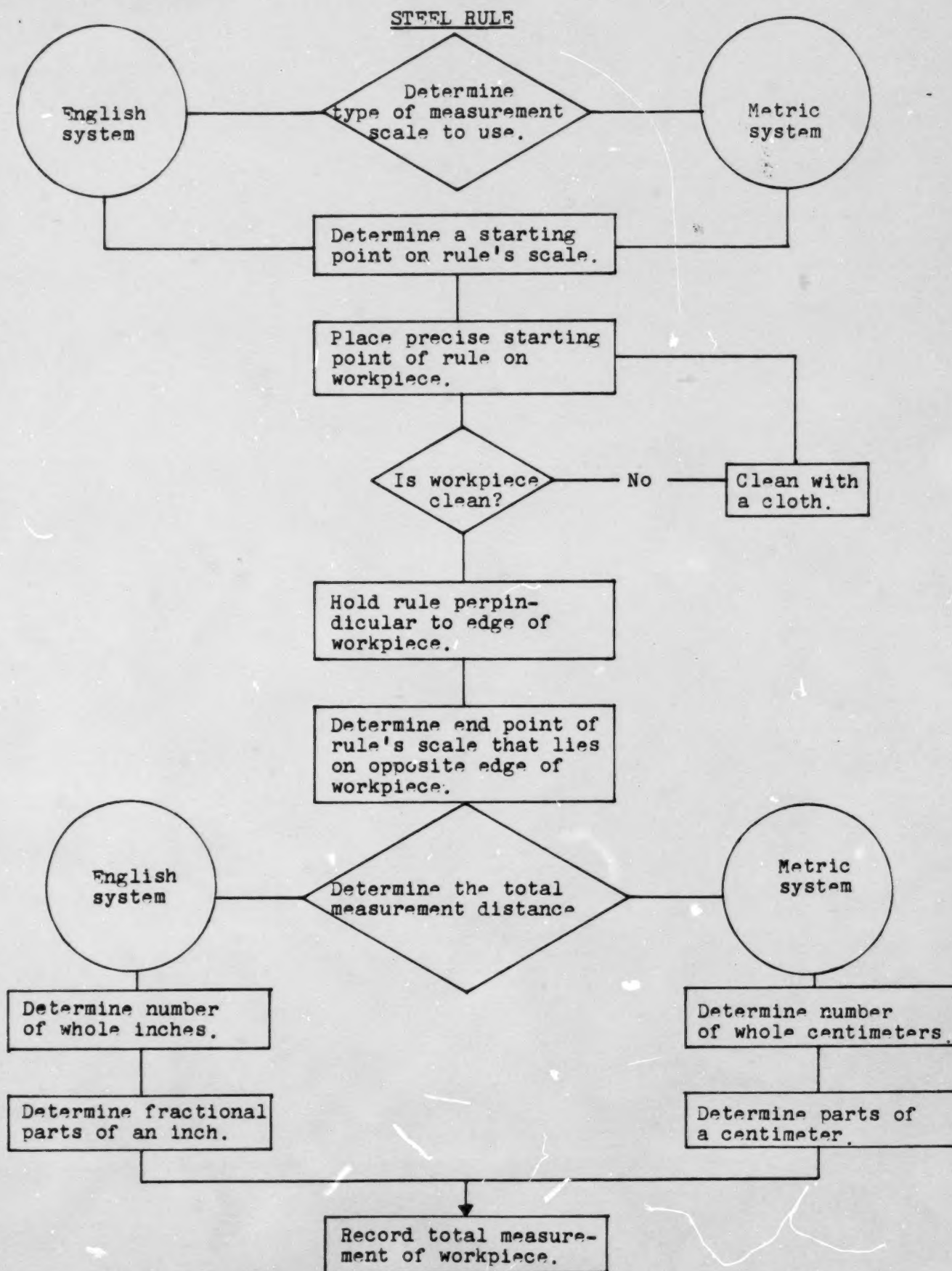
Measuring Instruments to be Used in Training:

1. English steel rule (12 inch)
2. Metric steel rule (approximately 12 inch)
3. Inch micrometer
4. English vernier caliper

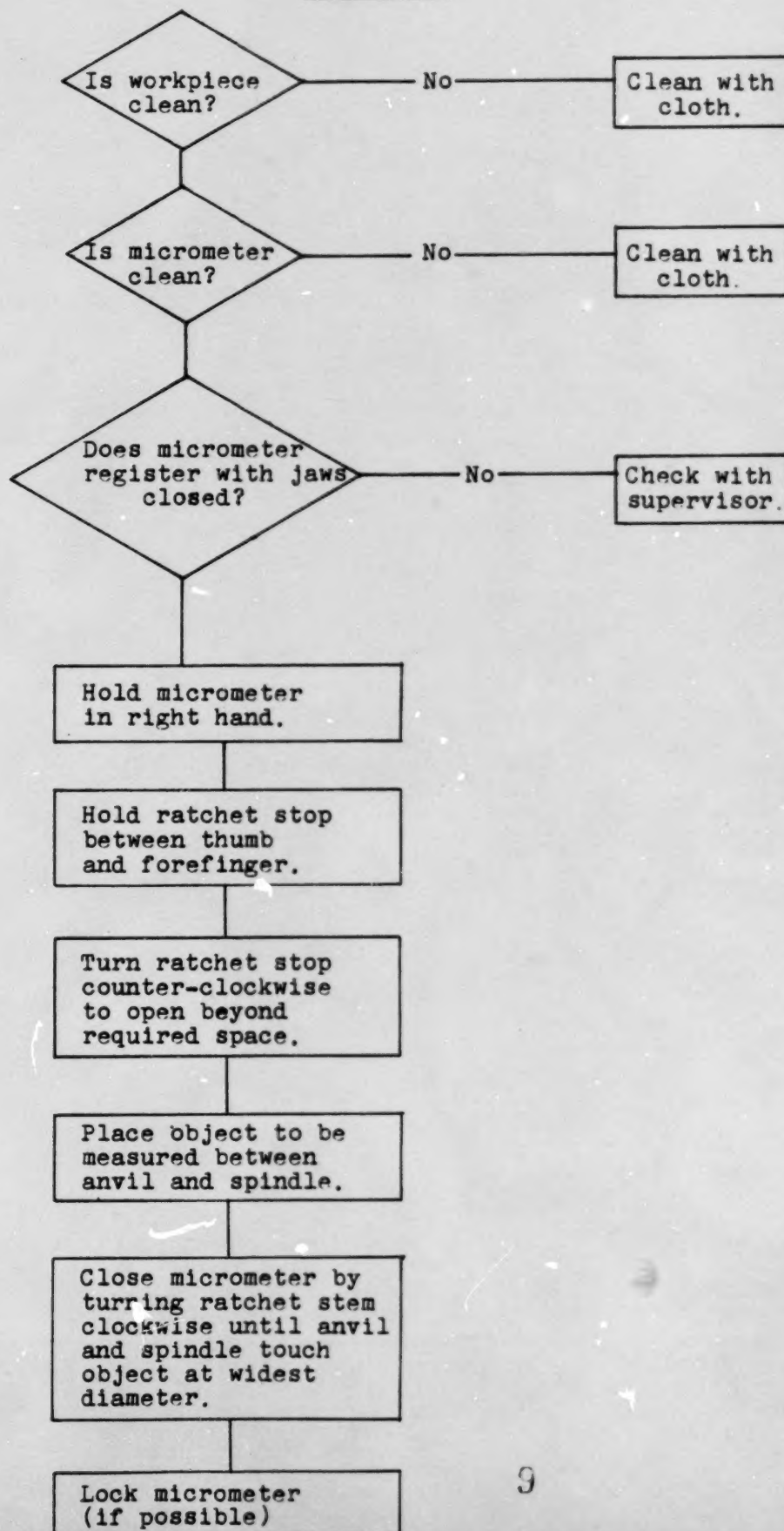
Objectives:

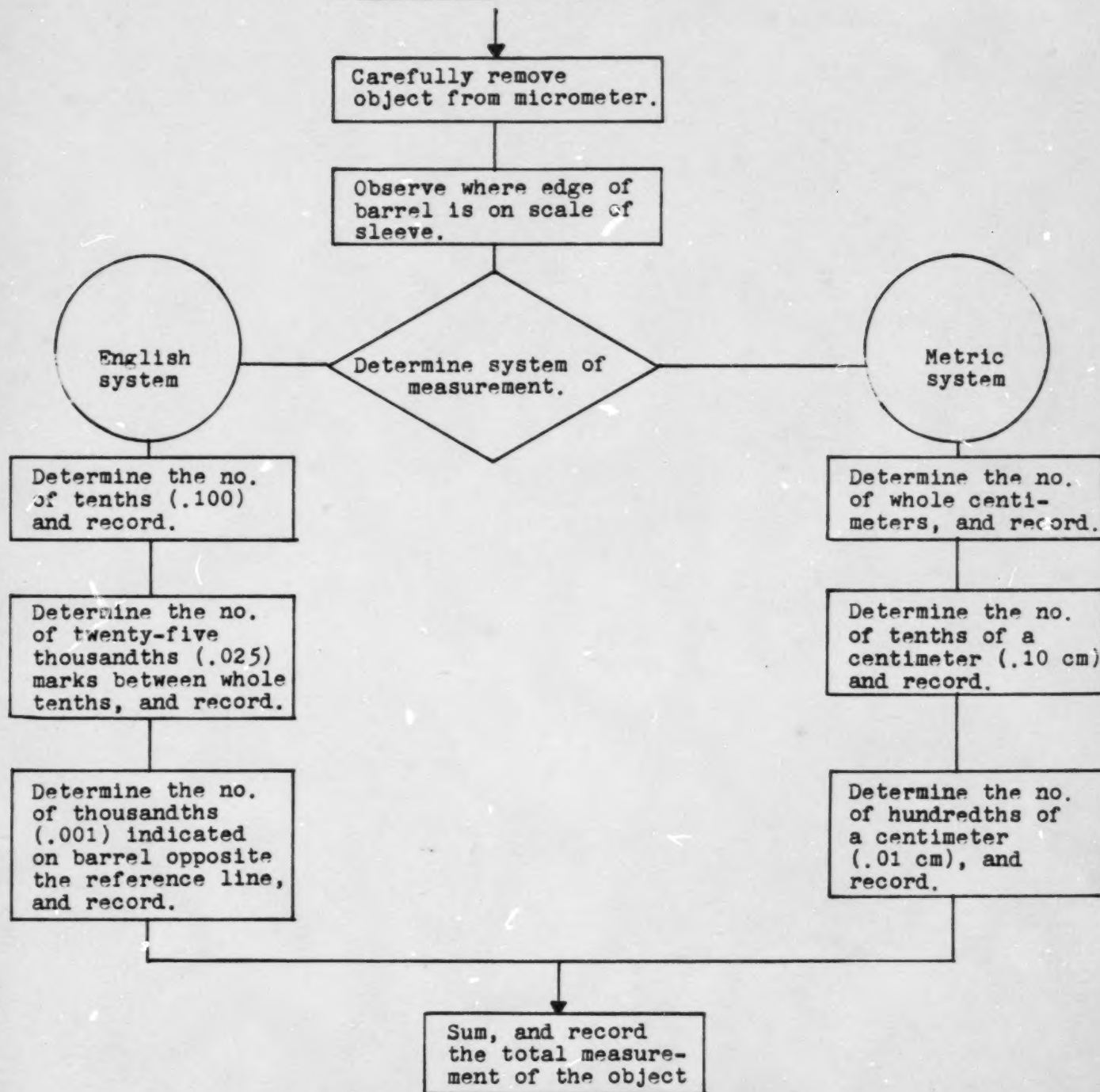
Following oral and written descriptions of the procedures to read the measuring scales of basic measuring instruments used by machinists, the trainee will be able to successfully complete the objectives listed below. The trainee will receive no oral or written assistance when completing the objectives after training.

1. Given diagrams of the basic measuring instruments used in the machine trades, the trainee will identify the basic parts of the instruments on illustrated diagrams with an accuracy of 100%.
2. Given an illustrated diagram of the measuring scales of the basic measuring instruments used in the machine trades, the trainee will identify the precise measurement shown by the diagram with an accuracy of 100%.
3. Given the basic measuring instruments used in the machine trades, the trainee will measure selected dimensions of machined steel parts, as determined by the instructor, to an accuracy of $\pm .002$ inch. The accuracy for measurements obtained by steel rules will be $\pm 1/32$ inch for an English rule and ± 1 millimeter for a metric rule.

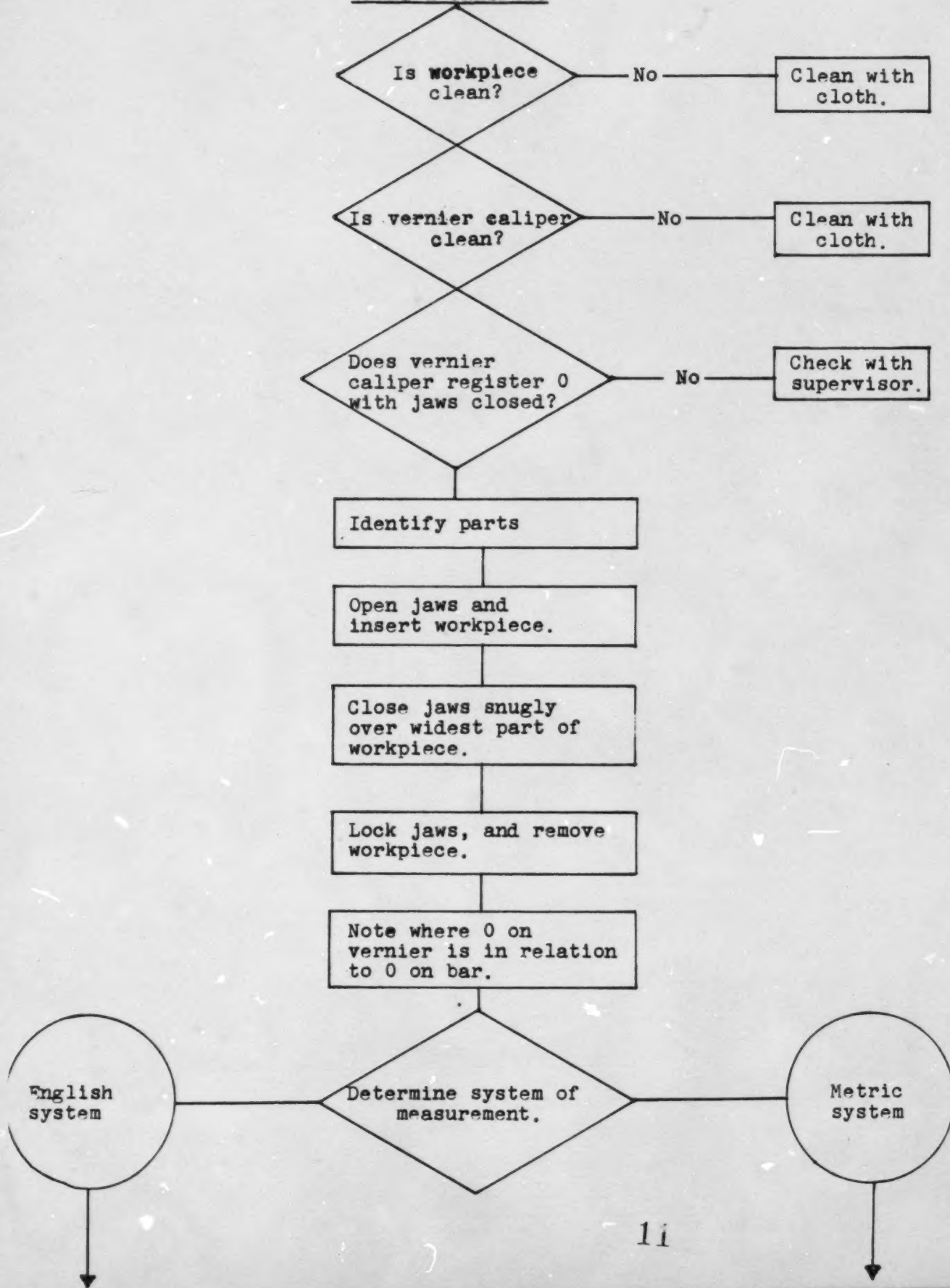


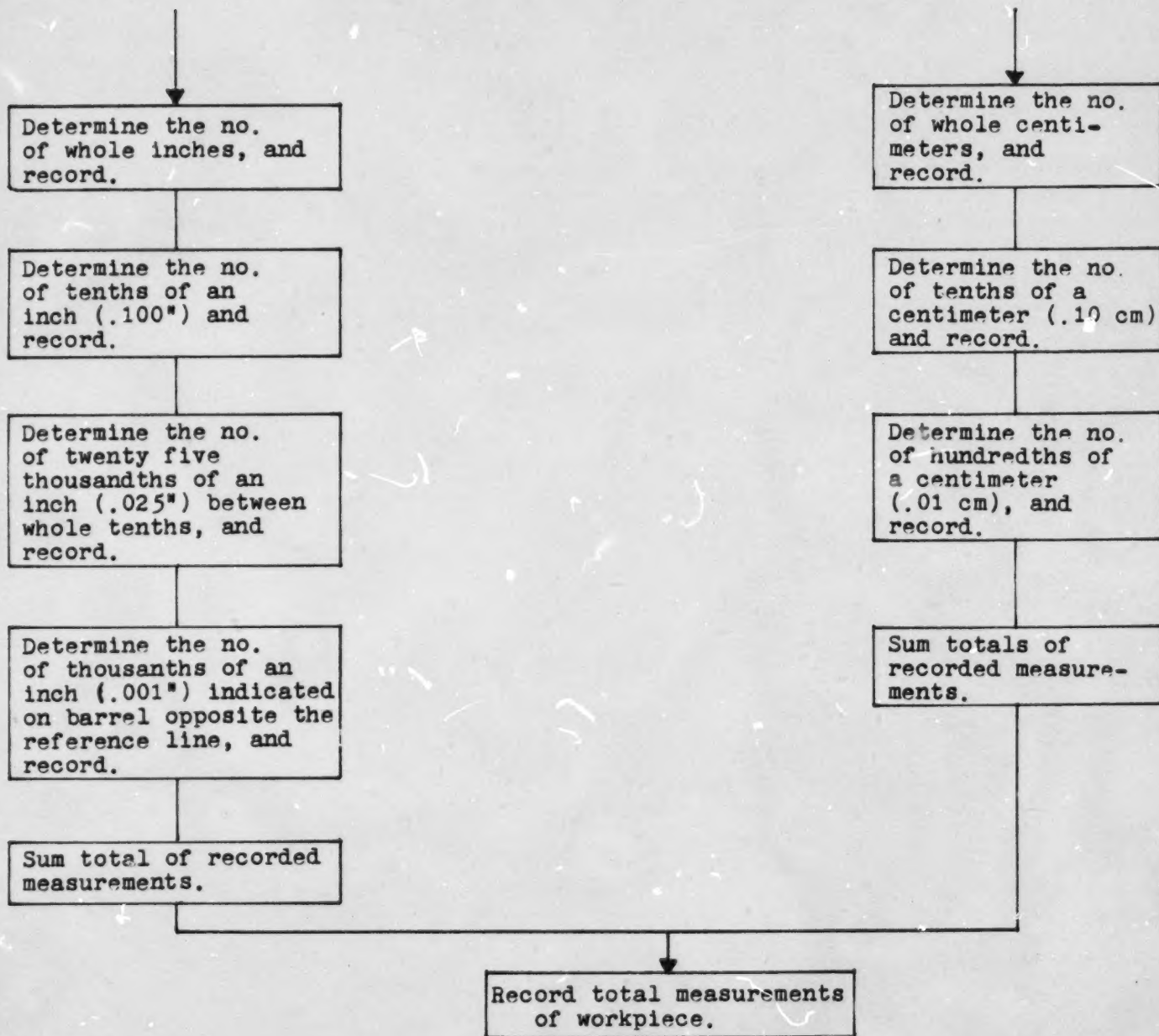
MICROMETER



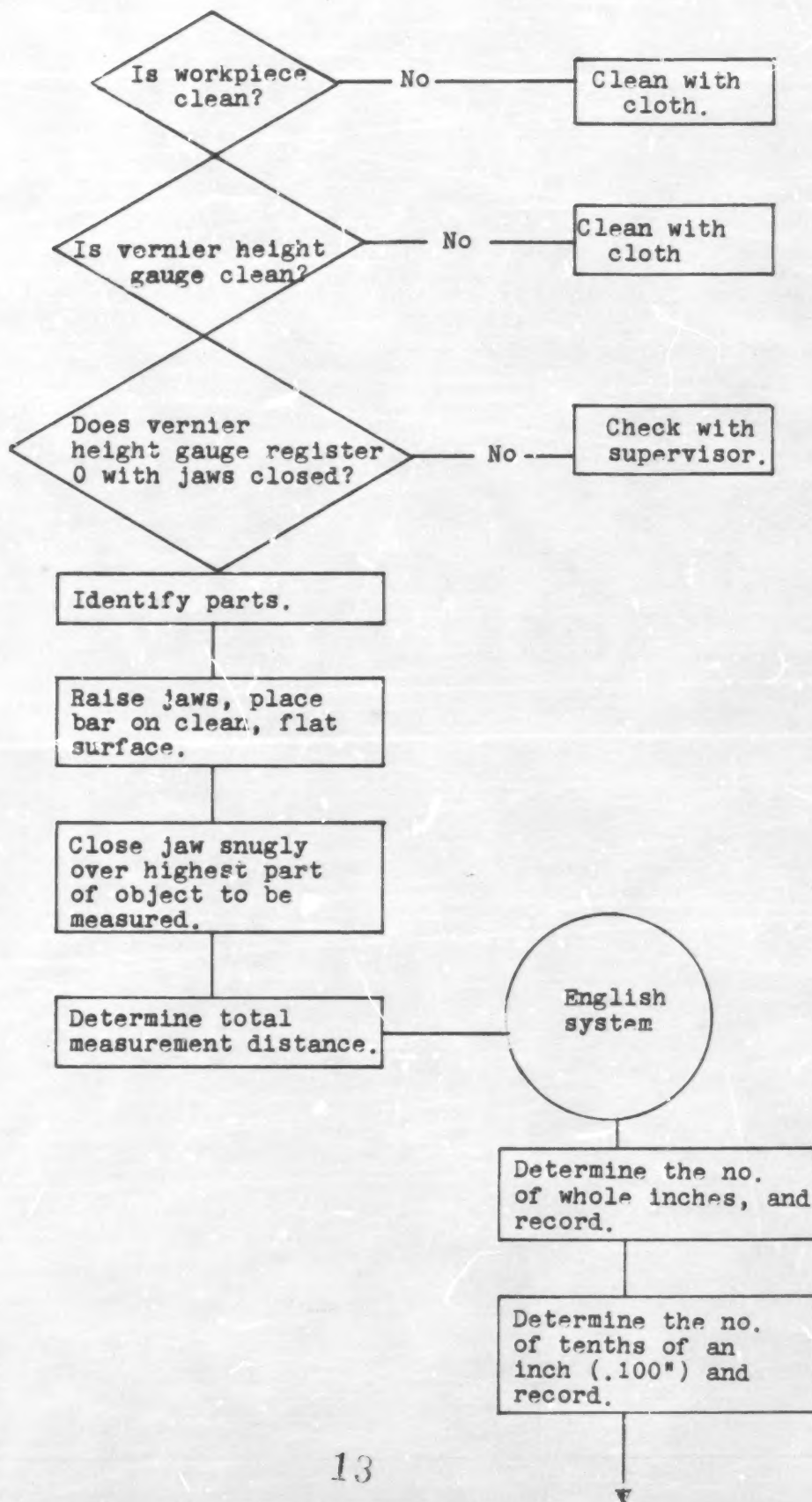


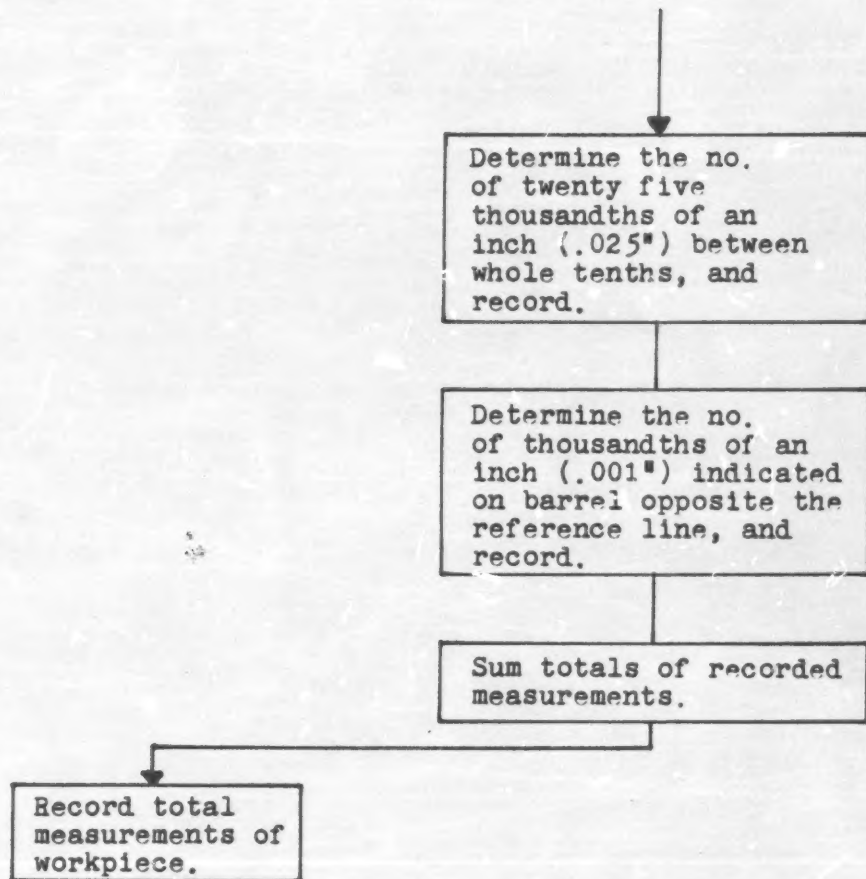
VERNIER CALIPERS





VERNIER HEIGHT GAUGE





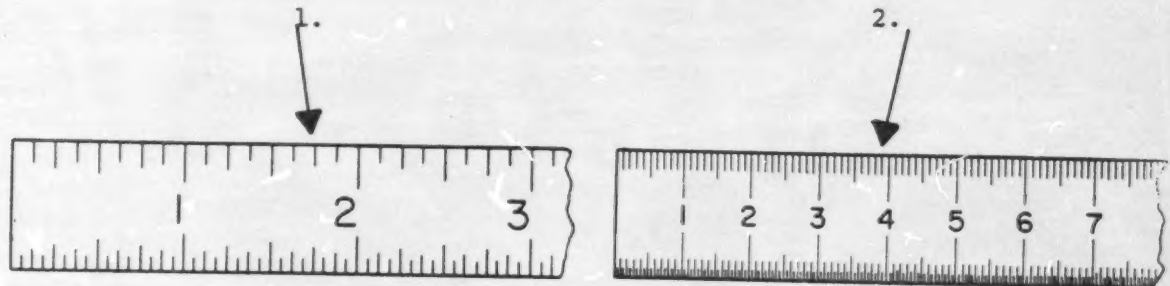
***** MEASUREMENT FOR MACHINISTS *****

TEST FORM A

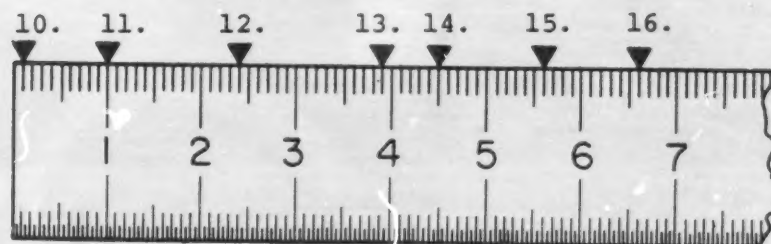
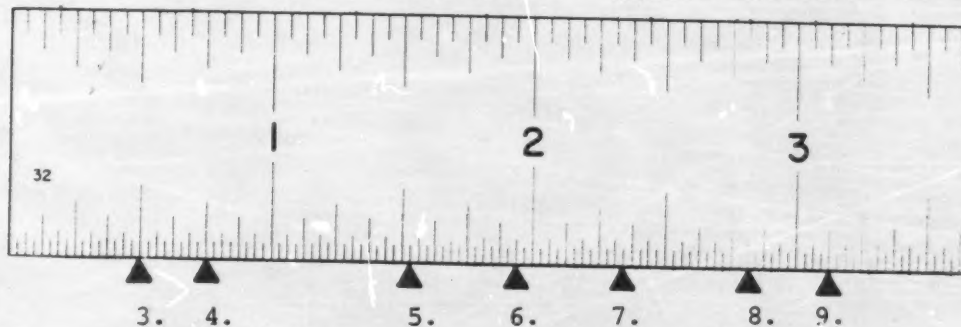
Answer the following questions on this test by writing the correct answer on the space provided on the test answer sheet. Work carefully! Record your answers as precisely and accurately as possible. Each response is worth one point.

GOOD LUCK!

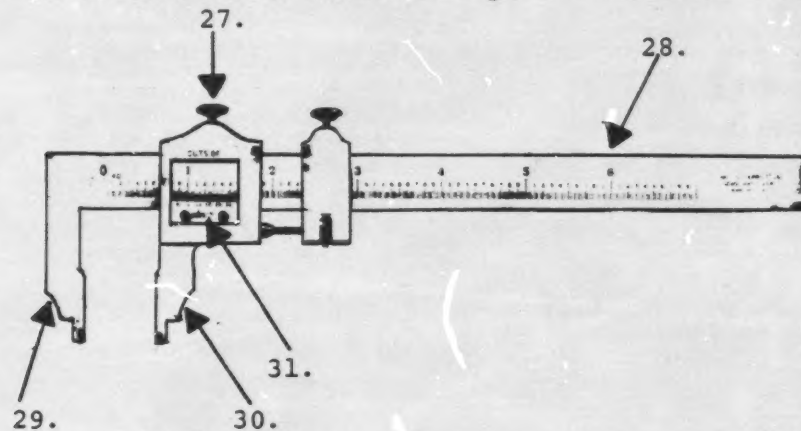
- A. Which two systems of measurement are represented by the following diagrams of a steel rule?



- B. Look carefully at these two pictures of a rule. Record the exact indicated measurements (as shown by the arrows). Be sure to include the units of measurement. Reduce fractions as far as possible!



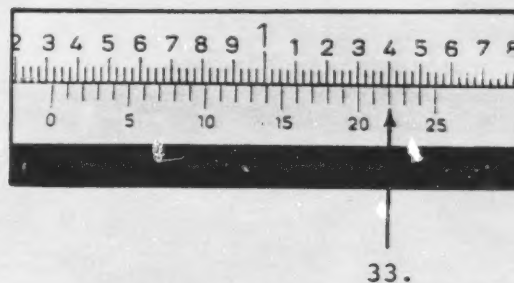
E. Identify and record the basic parts of a vernier caliper. The parts to be identified are indicated by the numbered arrows.



F. Look at each drawing carefully. Determine the exact measurement that is represented in the diagram of the scale of a vernier caliper. Record the indicated measurement on the answer sheet. Be sure to include the units of measurement.



32.

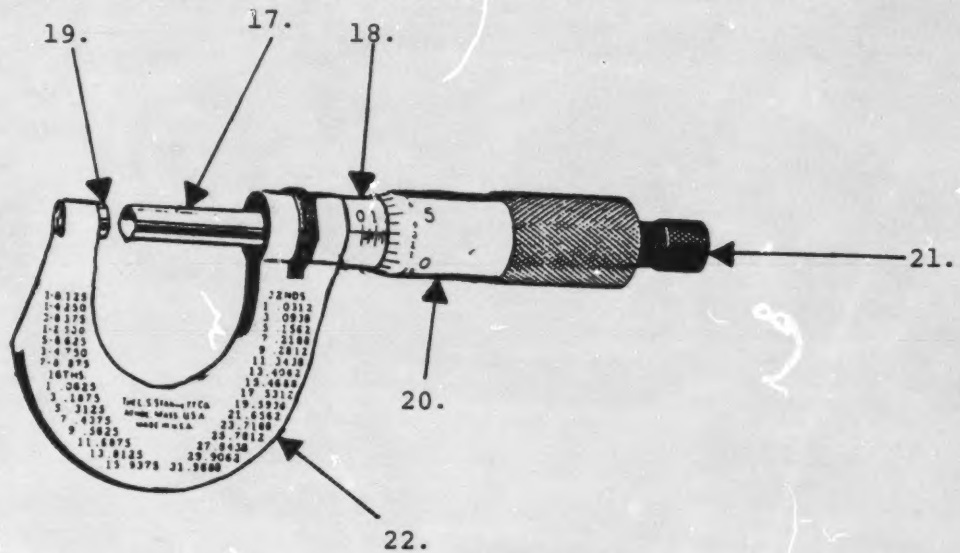


33.

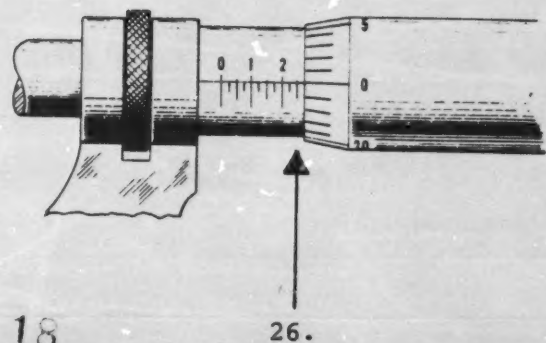
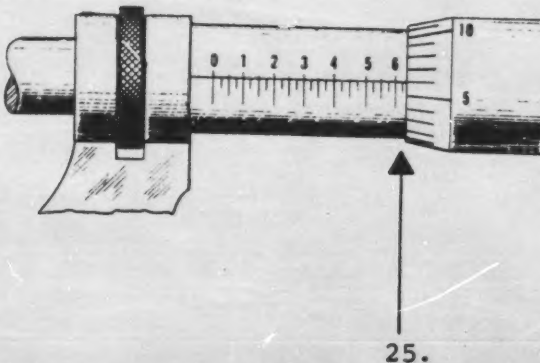
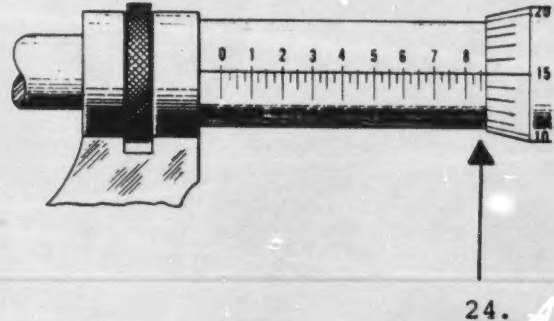
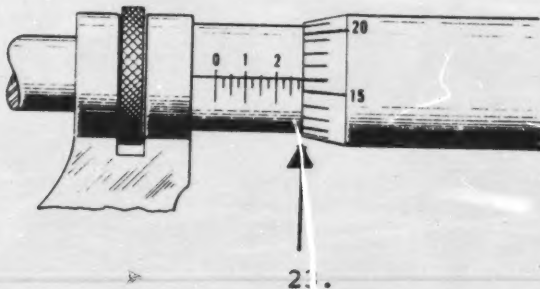


34.

- C. Identify and record the basic parts on this diagram of a micrometer. The parts to be identified are indicated by the numbered arrows.



- D. Look at each drawing carefully. Determine the exact measurement that is represented in the diagram of the scale of a micrometer. Record the indicated measurement on the answer sheet. Be sure to include the units of measurement.



NOTE: For the following exercises, you will need the numbered steel samples that will be provided by your instructor. You will also need an English/metric steel rule, inch micrometer, and an English vernier caliper.

- G. Using an English/metric steel rule, record the length, width, and thickness of the given steel plate. Record these measurements in the English system to the nearest $1/32$ ". Then record these measurements in the metric system to the nearest 1 mm.. Measurements should be exact. Reduce fractions to lowest possible!

plate 1 (English)

35. (length)

36. (width)

37. (thickness)

plate 1 (metric)

38. (length)

39. (width)

40. (thickness)

- H. Using an inch micrometer, measure the diameter of 3 steel rod samples, and the thickness of 3 steel plate samples. Your recorded measurements must be accurate to $\pm .002$ ". Be sure to include the units of measurement.

41. diameter rod 1

42. diameter rod 2

43. diameter rod 3

44. thickness plate 2

45. thickness plate 3

46. thickness plate 4

- I. Using an English vernier caliper, measure the outside diameter of 2 more steel rod samples, and the inside diameter of 2 steel cylinders. Your recorded measurements must be accurate to $\pm .002$ ". Be sure to include the units of measurement.

47. diameter rod 4 (outside)

48. diameter rod 5 (outside)

49. diameter cylinder 1 (inside)

50. diameter cylinder 2 (inside)

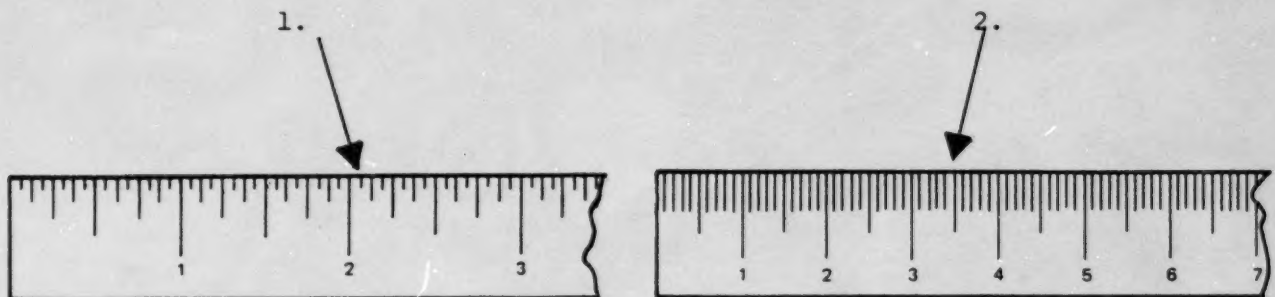
***** MEASUREMENT FOR MACHINISTS *****

TEST FORM B

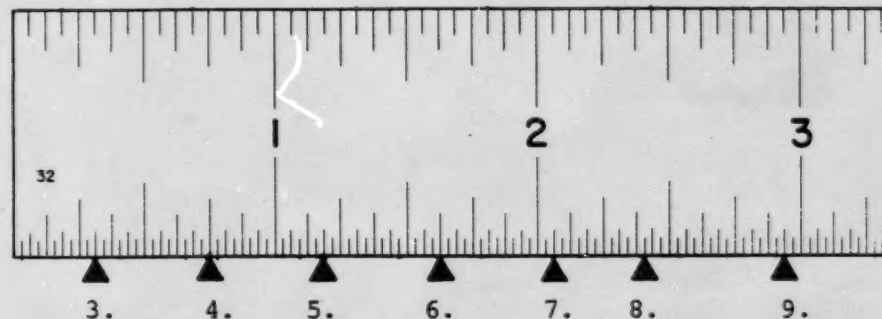
Answer the following questions on this test by writing the correct answer on the space provided on the test answer sheet. Work carefully! Record your answers as precisely and accurately as possible. Each response is worth one point.

GOOD LUCK!

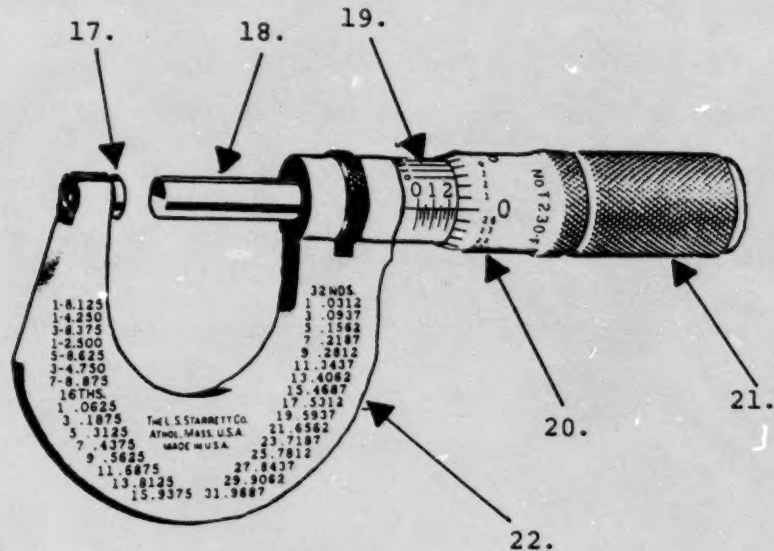
- A. Which two systems of measurement are represented by the following diagrams of a steel rule?



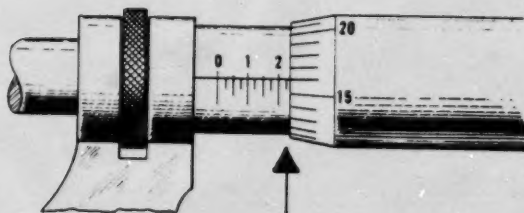
- B. Look carefully at these two pictures of a rule. Record the exact indicated measurements (as shown by the arrows). Be sure to include the units of measurement. Reduce all fractions to the lowest possible!



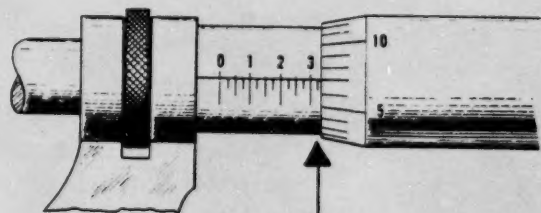
- C. Identify and record the basic parts on this diagram of a micrometer. The parts to be identified are indicated by the numbered arrows.



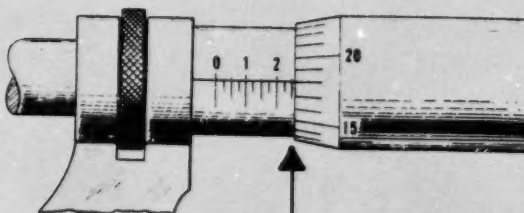
- D. Look at each drawing carefully. Determine the exact measurement that is represented in the diagram of the scale of a micrometer. Record the indicated measurements on the answer sheet. Be sure to include the units of measurement.



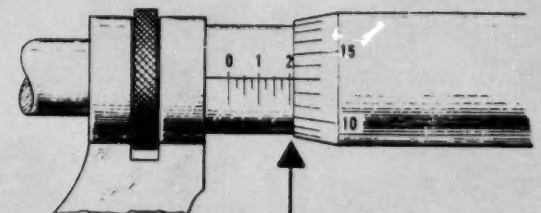
23.



24.

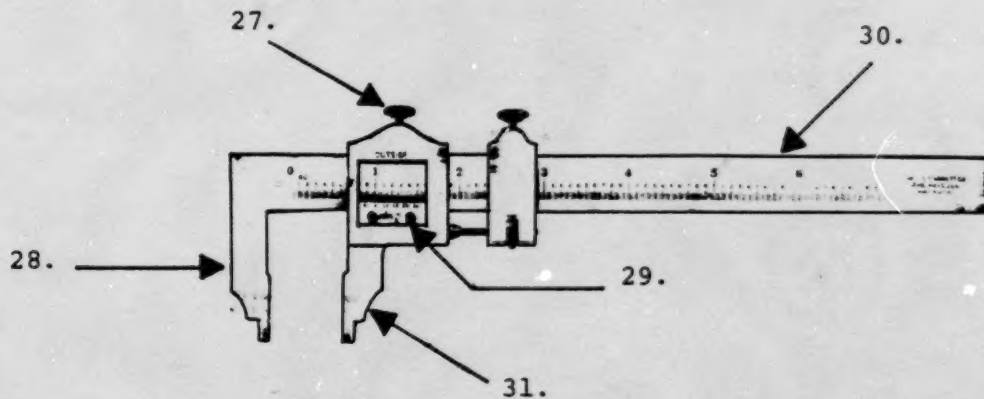


25.



26.

- E. Identify and record the basic parts of a vernier caliper. The parts to be identified are indicated by the numbered arrows.



- F. Look at each drawing carefully. Determine the exact measurement that is represented in the diagram of the scale of a vernier caliper. Record the indicated measurements on the answer sheet. Be sure to include the units of measurement.



32.



33.



34.

23

NOTE: For the following exercises, you will need the numbered steel samples that will be provided by your instructor. You will also need an English/metric steel rule, inch micrometer, and an English vernier caliper.

- G. Using an English/metric steel rule, record the length, width, and thickness of the given steel plate. Record these measurements in the English system to the nearest $1/32$ ". Then record these measurements in the metric system to the nearest 1 mm.. Measurements should be exact. Fractions should be reduced to the lowest possible!

<u>plate 1</u> (English)	<u>plate 2</u> (metric)
35. (length)	38. (length)
36. (width)	39. (width)
37. (thickness)	40. (thickness)

- H. Using an inch micrometer, measure the diameter of 3 steel rod samples, and the thickness of 3 steel plate samples. Your recorded measurements must be accurated to .002". Be sure to include the units of measurement.

41. diameter rod 1	44. thickness plate 2
42. diameter rod 2	45. thickness plate 3
43. diameter rod 3	46. thickness plate 4

- I. Using an English vernier caliper, measure the outside diameters of 2 more steel rod samples, and the inside diameters of 2 steel cylinders. Your recorded measurements must be accurate to .002". Be sure to include the units of measurement.

47. diameter rod 4 (outside)
48. diameter rod 5 (outside)
49. diameter cylinder 1 (inside)
50. diameter cylinder 2 (inside)

***** MEASUREMENT FOR MACHINISTS *****

ANSWER SHEET

Name: ANSWER KEY!

Test Form: A

Directions: Write your answer to each question on the lines provided.
The numbers on this answer sheet correspond to the numbers
in the test booklet.

- | | | |
|--|--------------------------------|-----------|
| 1. <u>English</u> | 22. <u>Frame</u> | 43. _____ |
| 2. <u>Metric</u> | 23. <u>.291"</u> | 44. _____ |
| 3. <u>$\frac{1}{2}"$</u> | 24. <u>.865"</u> | 45. _____ |
| 4. <u>$\frac{3}{4}"$</u> | 25. <u>.631"</u> | 46. _____ |
| 5. <u>$1\frac{17}{32}"$</u> | 26. <u>.275"</u> | 47. _____ |
| 6. <u>$1\frac{15}{16}"$</u> | 27. <u>Clamp Screws</u> | 48. _____ |
| 7. <u>$2\frac{11}{32}"$</u> | 28. <u>Bar (Steel)</u> | 49. _____ |
| 8. <u>$2\frac{13}{16}"$</u> | 29. <u>Fixed Measuring Jaw</u> | 50. _____ |
| 9. <u>$3\frac{1}{8}"$</u> | 30. <u>Movable Jaw</u> | |
| 10. <u>.1 cm or 1 mm</u> | 31. <u>Vernier Scale</u> | |
| 11. <u>1 cm</u> | 32. <u>3.066"</u> | |
| 12. <u>2.4 cm</u> | 33. <u>.322"</u> | |
| 13. <u>3.9 cm</u> | 34. <u>.702</u> | |
| 14. <u>4.5 cm</u> | 35. <u>*</u> | |
| 15. <u>5.6 cm</u> | 36. _____ | |
| 16. <u>6.6 cm</u> | 37. _____ | |
| 17. <u>Spindle</u> | 38. _____ | |
| 18. <u>Barrel</u> | 39. _____ | |
| 19. <u>Anvil</u> | 40. _____ | |
| 20. <u>Sleeve</u> | 41. _____ | |
| 21. <u>Ratchet Stop</u> | 42. _____ | |

* Answers for #35
through #50 will
vary, according
to the sizes of
the metal samples
that are used.

Scoring: Each answer is worth one point. There are 50 possible points.
Add the number of questions that the trainee answered correctly
to obtain a total score.

TOTAL SCORE: 25

ANSWER SHEET

Name: Answer Key!

Test Form: B

Directions: Write your answer to each question on the lines provided.
The numbers on this answer sheet correspond to the numbers in the test booklet.

- | | | |
|--------------------------|--------------------------------|-----------|
| 1. <u>English</u> | 22. <u>Frame</u> | 43. _____ |
| 2. <u>Metric</u> | 23. <u>.241 "</u> | 44. _____ |
| 3. <u>5/16 "</u> | 24. <u>.332 "</u> | 45. _____ |
| 4. <u>3/4 "</u> | 25. <u>.268 "</u> | 46. _____ |
| 5. <u>1 3/16 "</u> | 26. <u>.213 "</u> | 47. _____ |
| 6. <u>1 5/8 "</u> | 27. <u>Clamp Screws</u> | 48. _____ |
| 7. <u>2 1/8 "</u> | 28. <u>Fixed Measuring Jaw</u> | 49. _____ |
| 8. <u>2 15/32 "</u> | 29. <u>Vernier Scale</u> | 50. _____ |
| 9. <u>2 15/16 "</u> | 30. <u>Bar (Steel)</u> | |
| 10. <u>.6 cm or 6 mm</u> | 31. <u>Movable Jaw</u> | |
| 11. <u>1.7 cm</u> | 32. <u>.322 "</u> | |
| 12. <u>2.7 cm</u> | 33. <u>1.001 "</u> | |
| 13. <u>4.2 cm</u> | 34. <u>3.066 "</u> | |
| 14. <u>5.6 cm</u> | 35. <u>*</u> | |
| 15. <u>6.3 cm</u> | 36. _____ | |
| 16. <u>7.4 cm</u> | 37. _____ | |
| 17. <u>Anvil</u> | 38. _____ | |
| 18. <u>Spindle</u> | 39. _____ | |
| 19. <u>Barrel</u> | 40. _____ | |
| 20. <u>Sleeve</u> | 41. _____ | |
| 21. <u>Thimble</u> | 42. _____ | |

* Answers for #35 through #50 will vary, according to the sizes of the metal samples that are used.

Scoring: Each answer is worth one point. There are 50 possible points. Add the number of questions that the trainee answered correctly to obtain a total score.

TOTAL SCORE: 26

***** MEASUREMENT FOR MACHINISTS *****

ANSWER SHEET

Name: _____

Test Form: _____

Directions: Write your answer to each question on the lines provided.
The numbers on this answer sheet correspond to the numbers
in the test booklet.

- | | | |
|-----------|-----------|-----------|
| 1. _____ | 22. _____ | 43. _____ |
| 2. _____ | 23. _____ | 44. _____ |
| 3. _____ | 24. _____ | 45. _____ |
| 4. _____ | 25. _____ | 46. _____ |
| 5. _____ | 26. _____ | 47. _____ |
| 6. _____ | 27. _____ | 48. _____ |
| 7. _____ | 28. _____ | 49. _____ |
| 8. _____ | 29. _____ | 50. _____ |
| 9. _____ | 30. _____ | |
| 10. _____ | 31. _____ | |
| 11. _____ | 32. _____ | |
| 12. _____ | 33. _____ | |
| 13. _____ | 34. _____ | |
| 14. _____ | 35. _____ | |
| 15. _____ | 36. _____ | |
| 16. _____ | 37. _____ | |
| 17. _____ | 38. _____ | |
| 18. _____ | 39. _____ | |
| 19. _____ | 40. _____ | |
| 20. _____ | 41. _____ | |
| 21. _____ | 42. _____ | |

Scoring: Each answer is worth one point. There are 50 possible points.
Add the number of questions that the trainee answered correctly
to obtain a total score.

TOTAL SCORE: 27

The Training Package for Machinists has been developed to help the student gain basic skills in using some of the common measuring devices needed in the machine shop. It can be used as an instructional aid in conjunction with actual practice using the instruments.

The package consists of flow charts of the behaviors the trainee should master at each stage of instruction before proceeding to the next stage. To effectively utilize this package, the trainees must have access to instruments and premeasured work pieces that the instructor has prepared. It is important that the trainee be given an opportunity to make at least ten measurements in the training session with each instrument in order to provide sufficient practice. It is also important that the trainee be given feedback on these measurements so that he/she is reinforced for correct behavior. If there are several trainees, they can each measure and record the same object and compare readings. They may also compare their measurements with the measurement obtained by the instructor.

MEASURING THE LENGTH OF A STEEL WORKPIECE WITH AN ENGLISH STEEL RULE

Given:

A flat rectangular metal workpiece 12" long
Steel rule with metric and/or English scale

We will start with the rule. The rule comes in many different lengths, and in English or metric. We will use the 12" English and metric rule.

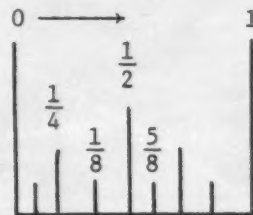
Note: The metric scale refers to divisions of centimeters and millimeters. The English scale refers to inch and fractional inch divisions.



Use of the Steel Rule

The steel rule found in the shop usually has a number stamped on it indicating the part of an inch that each graduation on the bottom edge represents. (For instance a #8 indicates that $1/8"$ is the smallest graduation.) If the rule has no number, it is always advisable to quickly determine the smallest division by counting down from the largest division (i.e., $1/2$, $1/4$, $1/8$, $1/16$ th, etc.). The most commonly used English rule has four sets of graduations with sixteenths and eighths of an inch on one side, and sixty-fourths and thirty-seconds of an inch on the opposite side.

Remember that when first using the rule, it is important to count down from the largest division ($1/2$) to smaller ones to make sure you have the correct division



The rule is one instrument that doesn't need calibration before you start the measurement. It does need to be correctly aligned, as shown. It can also get worn on the edges. Therefore to be more accurate with a measurement, measure from the 1" mark and subtract one inch, instead of measuring from the 0 mark.

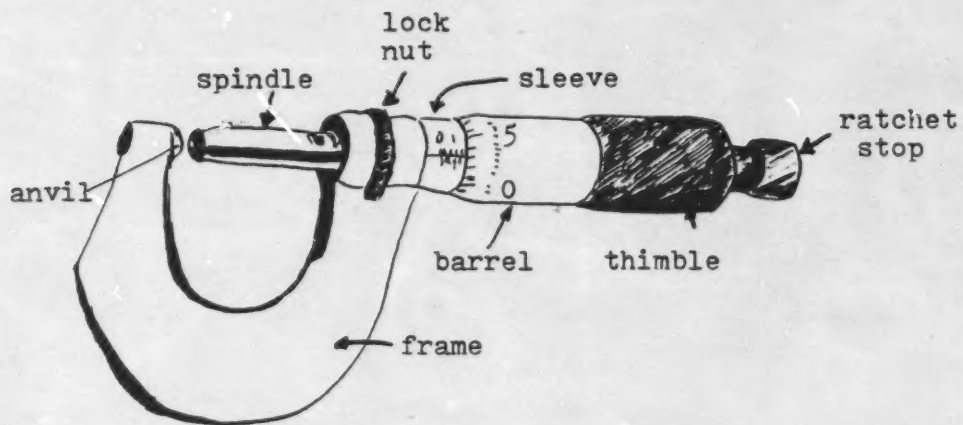
MEASURING THE DIAMETER OF A STEEL BAR WITH A MICROMETER

Given:

Steel bar 1" in diameter

Parts of a micrometer:

anvil
spindle
lock nut
sleeve
ratchet stop
thimble
barrel
frame



CARE OF THE MICROMETER

- *It's a measuring instrument. It must be handled with a great deal of care if its accuracy is to be maintained.
- *Oil the screw threads on the spindle to prevent wear and to preserve the threads. Wipe the micrometer with an oily rag to keep it clean.
- *Keep the face of the anvil and spindle clean to obtain maximum accuracy in your readings.
- *If the zero line on the thimble does not coincide with the zero line on the index line, loosen the cap on the end of the thimble. Reset the thimble to zero. Adjust to the correct position and tighten the cap.
- *When taking a measurement, use a very light pressure to obtain a correct reading. Remember the micrometer is not a C-clamp. Use only the finger tips to set the measurement.

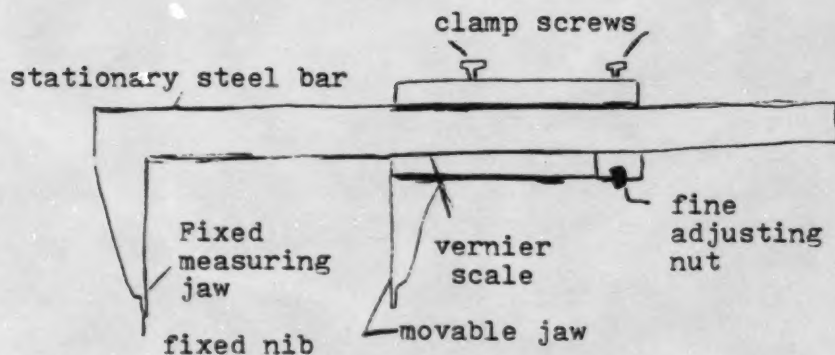
MEASURING THE DIAMETER OF A STEEL ROD WITH A VERNIER CALIPER

Given:

6" steel rod 2" in diameter

Parts of a caliper:

- fixed jaw
- movable jaw
- fixed nib
- vernier scale
- fine adjusting nut
- clamp screws
- stationary steel bar



Vernier Caliper, English

The vernier caliper can be used for making exact measurements across a larger area than the micrometer can measure. The zero on the sliding scale is the gauge line. The location of the zero in reference to the main scale determines part of the reading. The remainder of the reading is determined by the vernier scale, which is constructed as follows: a length equal to 24 graduations on the fixed or main scale or 0.600 is equal in length to 25 divisions on the vernier scale. Therefore, the scale is divided into 25 equal parts. Each space on the vernier is equal to $1/25$ of 0.600", or 0.024". The difference between the scale division and a vernier division is $0.025" - 0.024"$ or 0.001". If the tool is set so that the 0 line on the vernier scale coincides with the 0 line on the fixed scale, the line to the right of the 0 on the vernier will differ from the line to the right of the zero on the bar by 0.001". The second line will differ by 0.002", and so on. The difference will continue to increase by 0.001" for each division up to the 25th division which will coincide with line 24 on the beam.

To read the vernier caliper, note how many whole inches, tenths of an inch, and hundredths of an inch the zero mark on the vernier is from the zero mark on the beam. Then, add the number of thousandths indicated by the line on the vernier scale that exactly coincides with a line on the fixed scale.

When first using the vernier caliper, record and total your readings. It is relatively easy to mentally sum these measurements with a little practice. But, to get used to taking accurate measurements, record the first 20 measurements you make, and add them on paper.

Vernier Caliper, Metric

The vernier scale on the metric caliper is divided into 50 parts. Each part represents 0.02 mm. Every fifth line is numbered in sequence (i.e., 0.10 mm, 0.20 mm, etc.). This provides for direct reading in one-hundredths of a millimeter. In reading the gauge, count the number of millimeters between the zero line on the fixed bar and the zero line on the vernier scale. Find the graduation on the vernier scale that coincides with a line on the bar. Note its value in tenths of a millimeter, add the number of quarters. Add the vernier plate reading in one-hundredths of a millimeter to the number of millimeters you counted on the bar. Determine the total measurement by summing the parts.

$$\begin{array}{r} 1 \text{ mm} \\ 0.4 \\ .025 \\ .011 \\ \hline 1.436 \text{ mm} \end{array}$$

MEASURING THE HEIGHT OF A STEEL BAR WITH A VERNIER HEIGHT GAGE

Given:

Bar 3" in height

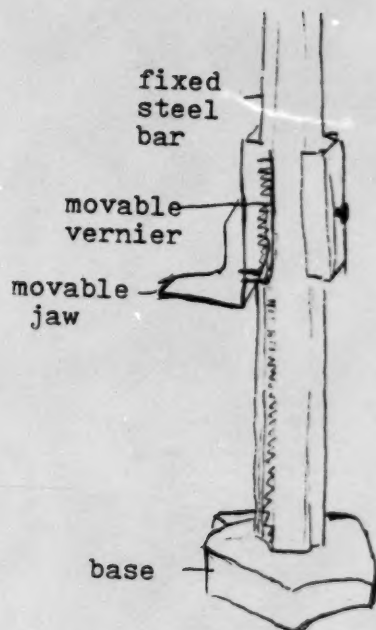
Parts of a vernier height gage:

fixed steel bar

movable vernier

movable jaw

base



The height gauge is virtually the same as the vernier caliper, except that it has only a single jaw and is used on a clean flat plate to measure height. Note that the moveable jaw must be flat on the base to register zero. There is an offset in the number scale to make up for the height of the base. The height gauge can also be used to mark a height on metal when a scribe is attached. Make sure that the point of the scribe attachment is turned to the zero surface, so that the mark it makes will be at the zero line.